Coastal Engineering Technical Note

PC Program for Coastal Inlet Stability Analysis Using Escoffier Method

By William C. Seabergh and Nicholas C. Kraus

PURPOSE

To provide information for determining coastal inlet stability using a personal computer program which is a tool in the Coastal Inlet Management Package of the Coastal Inlets Research Program. Background on the technique is presented, including discussion of an analytic model to calculate the inlet hydraulics and the required input.

BACKGROUND

Wave-generated and other currents along the coast move sand into the inlet channel, reducing its cross-sectional area. Inlet flow, produced by tidal, wind-generated, seiche-generated or river inflow currents, will tend to scour any deposition which reduces the channel cross section below its equilibrium value. This concept was first developed analytically by Escoffier (1940, 1977). He proposed a diagram for inlet stability analysis in which two curves are initially plotted (Figure 1).

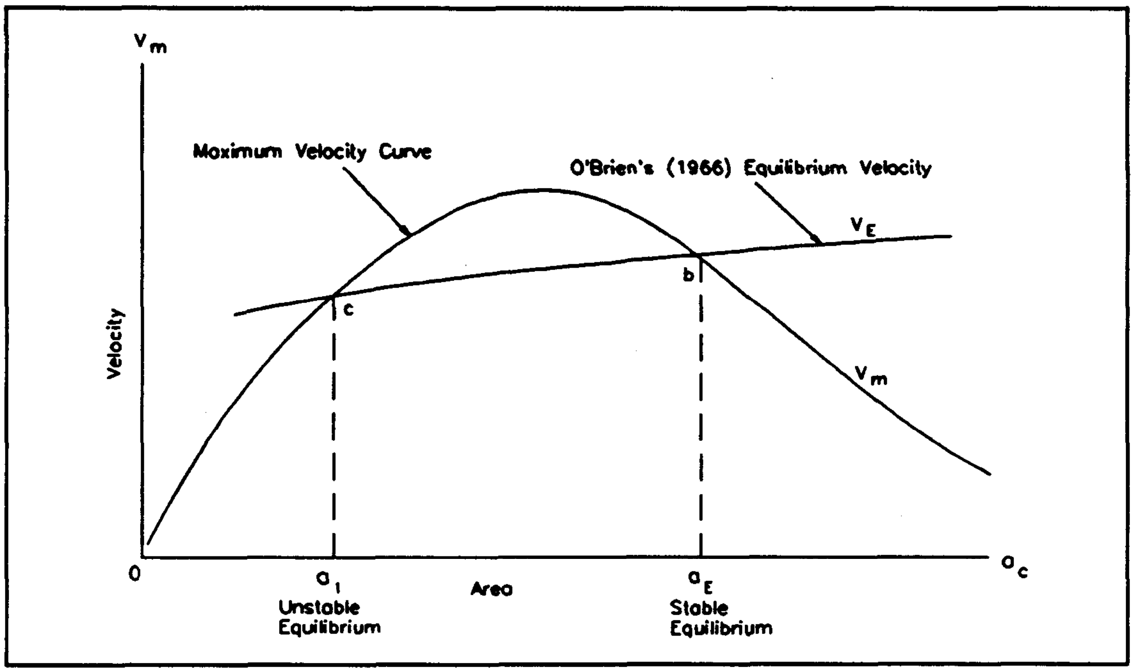

Figure 1. Escoffier (1940) diagram, maximum velocity and equilibrium velocity versus inlet cross-sectional area

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14. ABSTRACT **This Coastal Engineering Technical Note (CETN) provides information for determining coastal inlet stability using a personal computer program which is a tool in the Coastal Inlet Management Package of the Coastal Inlets Research Program. Background on the technique is presented, including discussion of an analytic model to calculate the inlet hydraulics and the required input.**						
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The first is the maximum velocity versus the inlet's cross-sectional flow area A_c. A single curve represents changing inlet cross-section area conditions if ocean tide parameters and bay and inlet plan geometry remain relatively fixed. As area approaches zero, velocity approaches zero because of increasing frictional forces, which are inversely proportional to channel area. As channel area increases, friction forces are reduced, but on the far right side of the curve, velocity decreases, as tidal prism has reached a maximum, and any channel area increases decrease velocity, as determined by the continuity equation. This curve can be constructed by calculating the maximum velocity V_m resulting by varying channel area A_c. V_m can be determined by an analytical or numerical model, remembering that, if a simple analytical model is used, an average maximum velocity for the inlet is determined. The continuity equation $V_{avg} A_{avg} = V_m A_c$ can then be used to determine maximum velocity at the minimum cross section. As a desk-study approach, because a variable area over the inlet length is not considered, a representative area will be considered the minimum area. The other curve, plotted as V_E, is an empirical stability criterion curve such as O'Brien's (1931) and Jarrett's (1976) tidal prism versus cross-section area relationships. Escoffier (1940) originally proposed a constant critical velocity, e.g., 1 m/sec, which would plot as a straight horizontal line. Dean (1971) equated the expression for tidal prism, $P = T\, V_m\, A_C / \pi$ to O'Brien's (1931) original tidal prism, inlet area relationship ($P = 5\text{x}10^4 A_c$) and determined that for a tidal period of 44,640 sec, V_m for the inlet is about 1 m/sec. In other words, 1 m/sec might be interpreted as a magnitude of velocity necessary to maintain an equilibrium flow area. Therefore, as wave action supplies sand to the inlet channel and tends to reduce the cross-sectional area, the inlet flow will scour any depositions which reduce the channel cross section below its equilibrium value. If a P versus A_c relationship is used (Table 1), the appropriate equation can be selected to relate V_m to tidal prism.

Table 1
Tidal Prism-Minimum Channel Cross-sectional Area Relationships

	Metric Units	American Customary Units
Atlantic Coast	$A_c = 3.039 \times 10^{-5}\ P^{1.05}$	$A_c = 7.75 \times 10^{-6}\ P^{1.05}$
Gulf Coast	$A_c = 9.311 \times 10^{-4}\ P^{0.84}$	$A_c = 5.02 \times 10^{-4}\ P^{0.84}$
Pacific Coast	$A_c = 2.833 \times 10^{-4}\ P^{0.91}$	$A_c = 1.19 \times 10^{-4}\ P^{0.91}$
Dual-Jettied Inlets (O'Brien)	$A_c = 7.489 \times 10^{-4}\ P^{0.86}$	$A_c = 3.76 \times 10^{-4}\ P^{0.86}$

NOTE:
A_c is the minimum cross-sectional area in square meters (square feet), P is the tidal prism in cubic meters (cubic feet).

In Figure 1, the possibilities of intersection of the two curves are at two locations, one location (a tangent), and no intersection. In the first case, Point b is a stable root in that any deviation in area returns movement along the stability curve to its starting point. If channel area increases (moves right on the curve from Point b), velocity will fall and more sediment can fill in the channel to bring it back to "equilibrium." If area decreases, velocity will increase, scouring to the equilibrium point. Point c is an unstable root, where if the area decreases, velocities decrease until the inlet closes. Moving to the right of Point c, as velocity increases, area increases until the

velocity starts falling and the stable root at Point b is reached. If the stability curve falls tangent to or below the stability criterion curve, the inlet will close. If the inlet area is to the right of the unstable equilibrium point, and a storm occurs which provides a large sediment input to the inlet region, a possibility would exist that it could shift the area to the left of that point and the inlet will close. Van de Kreeke (1992) presents informative commentary on application of Escoffier's analysis, where he notes that separation of stable and unstable inlets is not determined by the maximum in the maximum velocity curve (sometimes called the closure curve) of Figure 1, but Point c of that curve. Also, he emphasizes the integral use of O'Brien type stability correlations plus Escoffier's curve, rather than the use of stability equations alone.

HYDRODYNAMIC MODEL

The hydrodynamics are calculated from the analytical solution of DiLorenzo (1988) to determine a maximum current velocity in the inlet and the amplitude of the bay tide plus its phase lag from ocean high water. The typical approach for the user would be to calibrate the hydrodynamic model before doing the full analysis to determine inlet equilibrium area. Input parameters for the calibration phase are input via a pop-up menu (shown in Figure 2 below). This menu is brought up by right-clicking on "Project" sub-headings, "Calibration" or "Alternative," and input data include:

Under "Hydro Variables" pull-down tab-

Fundamental ocean tide amplitude. This value is one-half the tide "range" (range equals the full excursion of the tide). For equilibrium area calculations, spring tide amplitude is typically used. The M2 tidal component can be used (as DiLorenzo does for investigating flow dominance in conjunction with using the M4 tidal harmonic).

Ocean overtide amplitude. If information is available for tidal constituents, the M4 overtide amplitude may be used. This will permit an analysis of flow predominance for the inlet, i.e., whether there is flood or ebb dominance, characterizing typical net sediment transport.

Tidal or Seiche Period. For typical west and east coast semidiurnal tides, enter 12.42 hours. For Gulf Coast diurnal tide, enter 24.84 hrs. For Great Lakes inlets, enter seiche period in hours.

Under "Inlet Geometry" pull-down tab-

Channel area. For the calibration, a minimum inlet area that existed during the time period that prototype tidal elevation and/or velocity data exist for comparing with model data should be entered. For the alternatives evaluation, the model calculates over a range of areas, and the area value entered can be modified to ensure that the calculations cover the range of values necessary to determine the equilibrium area.

Tidal mean basin surface area. A mean surface area of the bay or lagoon is entered.

Hydraulic radius. Because typical inlets are relatively wide, this value could be considered an average depth and determined by dividing channel area by width.

Channel length. This parameter will probably be the primary one to vary in the calibration phase. The simplest initial approximation would involve examination of a plan view of the inlet. Determine where enlargement of the cross-sectional area would cause velocities to significantly

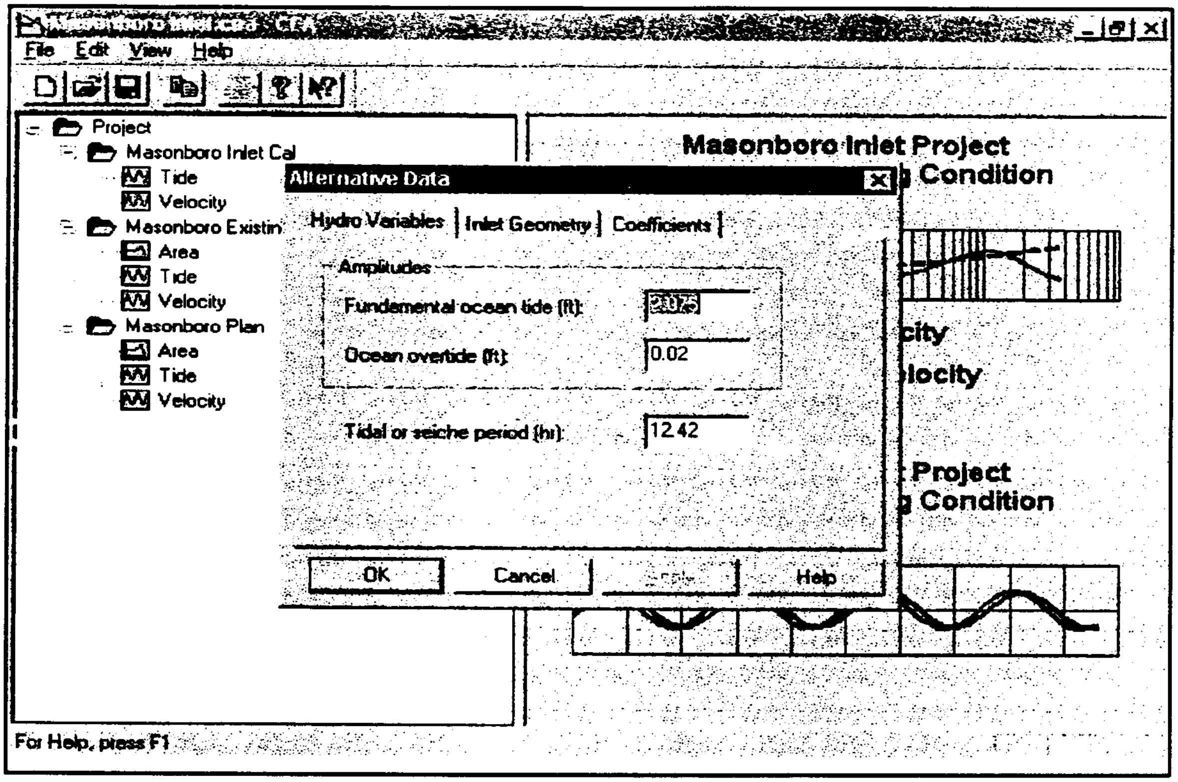

Figure 2. Pop-up screen for entering required inlet data

decrease at the seaward and bayward ends of the channel. Then use the distance between these two points as initial length.

<u>Channel width</u>. Use the width at the minimum cross-sectional area.

Under “”Coefficient” pull-down tab-

<u>Ken</u>. Choose a value from 0.05 for this entrance loss coefficient, for a relatively streamlined inlet, to 0.25, for an inlet with dual jetties.

<u>Kex.</u> A value of 1.0 for the exit loss coefficient describes a relatively deep bay and complete loss of kinetic head. Smaller values may be tried during calibration. The Ken and Kex values will not have a significant impact for friction-dominated inlets.

<u>Manning's Coefficient (*n* value)</u>. This bed resistance parameter may have typical values between 0.025 and 0.050 for inlets. This parameter can be adjusted during the calibration phase.

After entering the calibration parameters, the model quickly runs and produces tide and velocity curves which can be compared to prototype data. Calculations can be reiterated until reasonable agreement is reached. Figure 3 below shows the appearance of calculated ocean and bay tides.

After calibration, the user selects alternative plans after right-clicking the mouse button on any main heading on the left side of the screen. Typically the user would want to examine where the

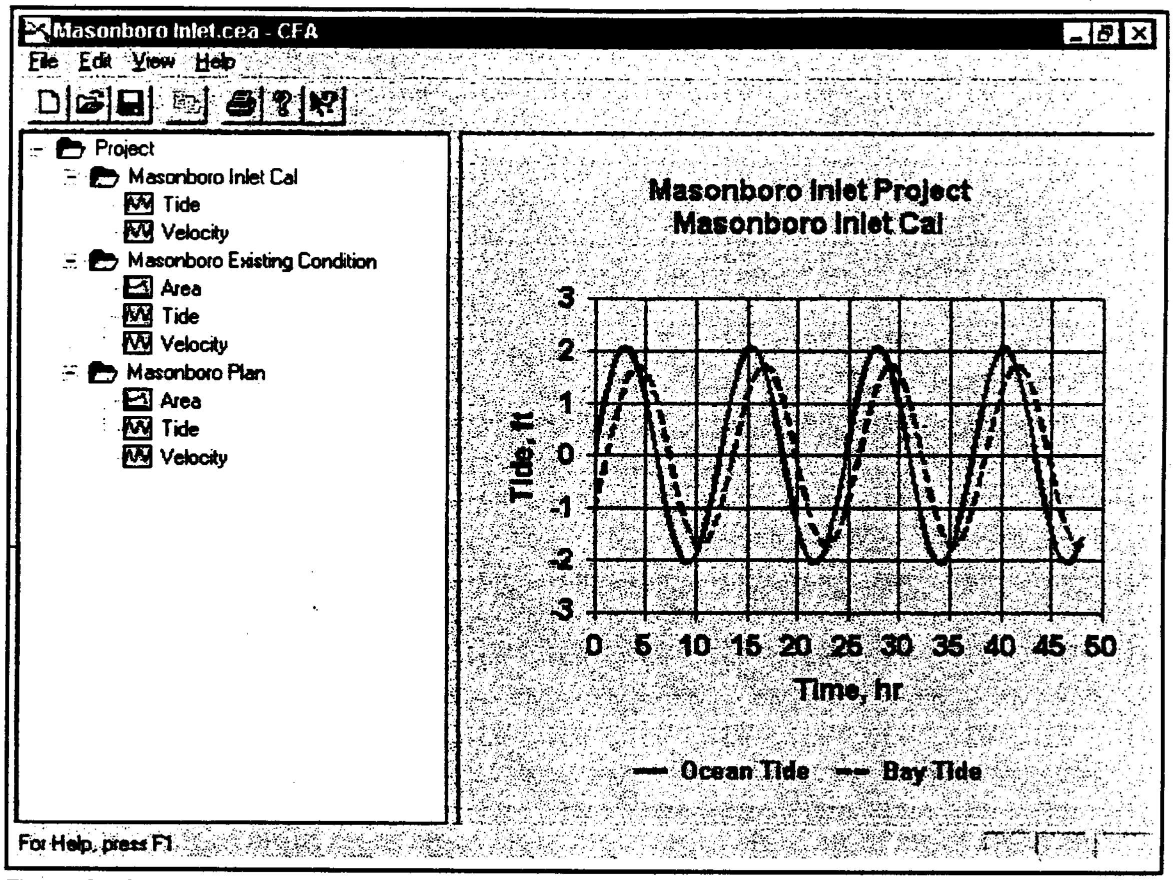

Figure 3. Screen showing calculated ocean and bay tides plotted for calibration phase where the model results are compared to data from the actual inlet

existing inlet is located on the inlet stability curve with respect to the equilibrium area. Thus, the same parameters for the inlet calibration might be copied for the calculations if the parameters are representive of the existing condition. Figure 4 shows the equilibrium-area plot. The equilibrium area can be determined from the right-hand intersection of the two velocity-area curves. The equilibrium area is also recorded in a table which appears in the right-side window when the "Project" heading on the left window is selected. This table summarizes all the various alternatives evaluated. Figure 5 shows a portion of the table which is easily printed out in its entirety. The program includes help files which explain all phases of operation and definitions of the various parameters.

ADDITIONAL INFORMATION

For further information, contact Mr. Bill Seabergh or Dr. Nicholas Kraus, U.S. Army Engineer Waterways Experiment Station, Coastal and Hydraulics Laboratory, at (601)634-3788 or (601)634-2016, respectively, or Internet b.seabergh@cerc.wes.army.mil or n.kraus@cerc.wes.army.mil.

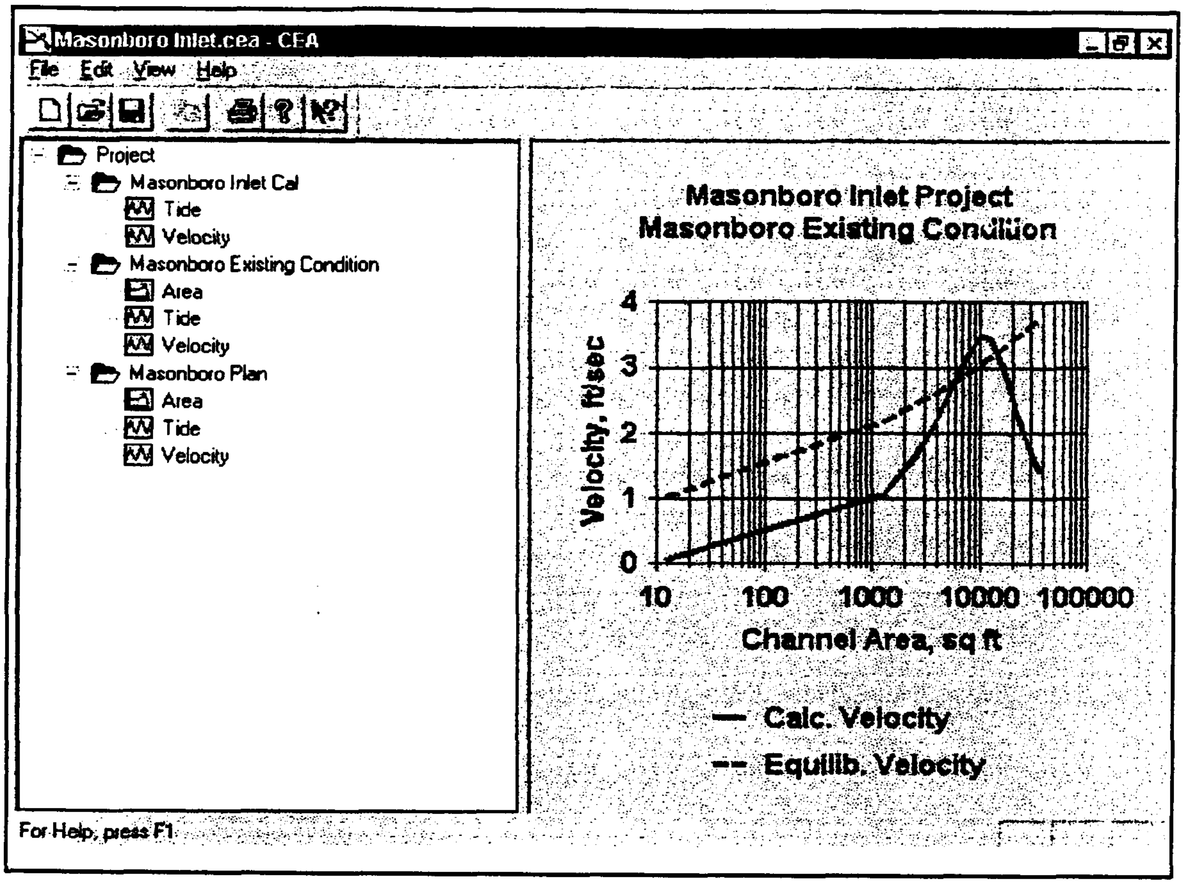

Figure 4. The equilibrium area is determined from the right-hand intersection of the two velocity-area curves

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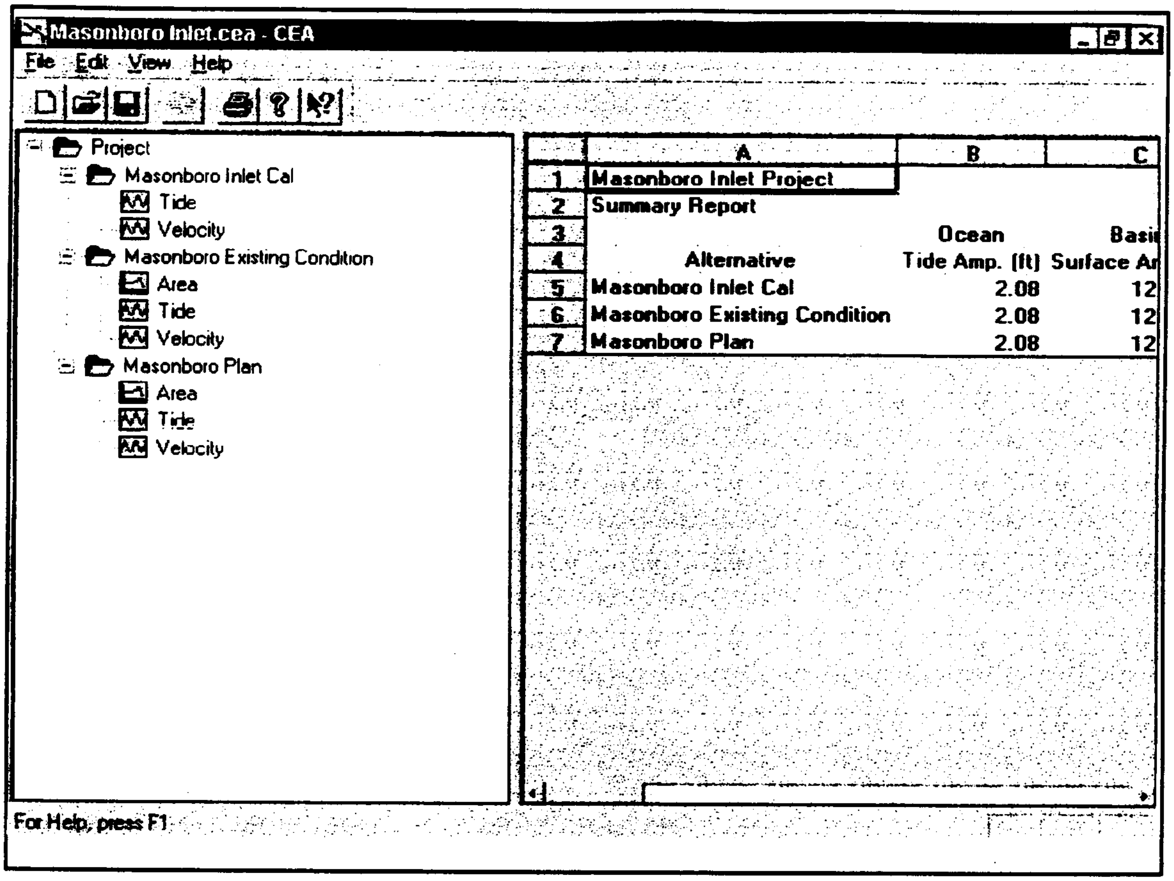

Figure 5. Inlet summary report screen which includes a table line for each alternative examined and which includes the calculated equibrium area